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# TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

# MINERALOGY, PHYSICAL AND EXCHANGEABLE CHEMISTRY PROPERTIES OF BENTONITES FROM THE WESTERN UNITED STATES, EXCLUSIVE OF MONTANA AND WYOMING

by

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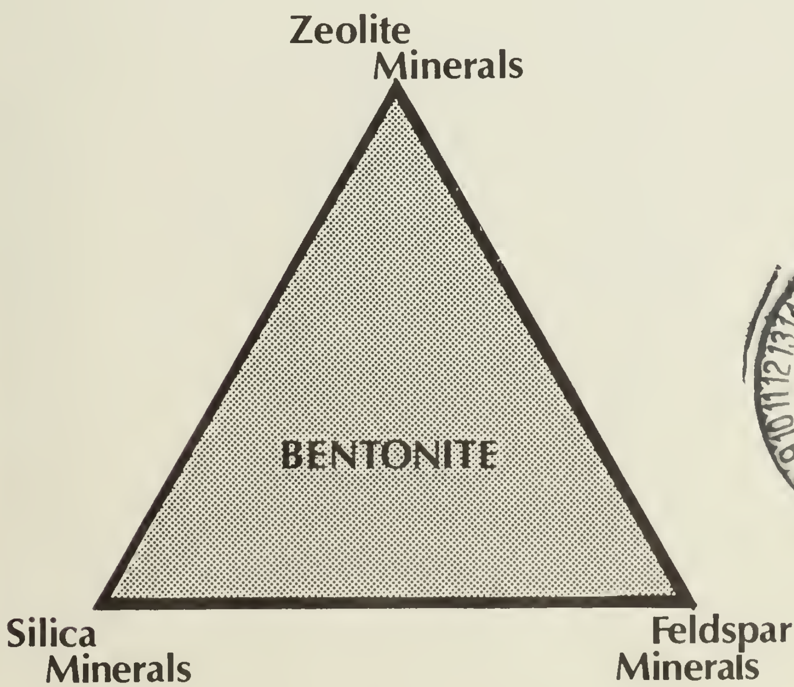




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Mineralogy, Physical and Exchangeable Chemistry Properties of Bentonite from the Western United States, Exclusive of Montana and Wyoming


## ABSTRACT

Investigations of predominantly Tertiary age bentonite deposits in the far western states show that these bentonites are primarily of the Ca and Ca-Na intermediate types. High Na bentonites in Tertiary formations are rare but do occur in isolated instances. Almost all of the bentonite deposits examined have viscosities of less than 70 bbl/ton and water loss in excess of 20 ml. This would indicate their main use to be as pond or reservoir sealants, pet adsorbents and animal feed binders. The available tonnages of these bentonitic materials are large, and in most cases, are heavily located by mining claims.

The bentonite deposits also have large amounts of other mineral phases, mainly zeolites, silica minerals, feldspar minerals and gypsum. In some cases, sepiolite also occurs, especially in areas suspect of any hydrothermal activity.

Zeolites, chiefly clinoptilolite, are so common in the Tertiary age bentonites that in some deposits, the claimants were mining and selling zeolites instead of bentonite. In these deposits the claimants were of the belief that they were selling bentonite. This would indicate that zeolites apparently can substitute or at least are suited to the same uses as Ca or intermediate Ca-Na bentonites.

## INTRODUCTION

In an effort to determine the chemical, mineralogical and physical properties of bentonites occurring on BLM lands in the Western United States, selected deposits were sampled in Oregon, California, Nevada, Utah, Arizona and Idaho. Most of these deposits were sampled in 1977. The deposits are all Tertiary in age except the one from Utah which is Cretaceous. All of the bentonite localities have had some past production, and are currently under mining claims.

In most cases, samples were collected from operating pits and bentonite beds in the proximity of such pits. The samples were then analyzed to determine the following properties:

1. Exchangeable Chemistry

2. Mineralogy

3. Physical Properties - viscosity in various solution media, and water loss

This report, therefore, treats only the above properties of the bentonite and in no way is meant to be a validity determination of any of the deposits.

A. Sample Locations

Shown in Figure 1 is an index map of the Western United States showing the bentonite localities.

General descriptions of the deposits are:

California

1. Coyote Mountains - Imperial County
   Sec. 6, T16S., R9E.

2. El Centro - Imperial County
   Sec. 19, 20, 29, 30, T14S., R12E.

3. Gunn Deposit - San Bernardino County
   Sec. 22, T10N., R2E.

4. Summit Range - San Bernardino County
   Sec. 29, 30, 31, 32, T28S., R41E.

Oregon

1. Camp Creek Area - Crook County
   Sec. 33, 34, T18S., R21E.
   Sec. 4, T19S., R21E.


California
1. Coyote Mtns.
2. El Centro
3. Gunn
4. Summit Range

Oregon
1. Camp Creek

Nevada
1. Amargosa

Arizona
1. Welton

Utah
1. Blanding

Idaho
1. Ben-Jel
2. OG

Figure 1. Index Map Showing Bentonite Localities.

Nevada

1. Amargosa Valley - Nye County

Arizona

1. Welton - Yuma County
   Sec. 1, T8S., R18W.

Utah

1. Blanding - San Juan County
   Sec. 12, T36S., R22E.

Idaho

1. Ben-Jel Deposit - Owyhee County
   Sec. 29, T5S., R1E., B.M
2. Opalene Gulch Deposit - Owyhee County
   Sec. 14, T1N., R4W., B.M

ANALYTICAL TECHNIQUES

A. X-Ray Diffraction Studies

Selected samples were examined for mineralogical phases and clay content by x-ray diffraction. In some cases, samples were run by both oriented and unoriented techniques in order to show both clay mineralogy and general mineralogical content. Samples were scanned from 60°2θ down to 3°2θ/minute. All x-ray diffraction interpretations were done by the author.

Major phases were arbitrarily selected as those whose major diffraction line had an intensity which exceeded a scale of 50 on the XRD pattern. Minor phases had intensities less than 50. The determination of Ca or Na montmorillonite was made by measurement of the (001) diffraction line. General guideline used consisted simply of calling all (001) reflections with spacings less than 6°2θ or greater than 14.7Å as calcium rich bentonite, and those with spacings greater than 6.5°2θ or less than 13.5Å as high sodium bentonites. Montmorillonite with a (001) peak between 6.0 and 6.5°2θ were simply referred to as intermediate or mixed Ca and Na bentonite. This procedure is not meant to be exact but only to indicate high sodium and calcium bentonites. The technique does appear to make this distinction, as shown by comparing the x-ray determination with the Na/CaMg ratios obtained on the samples.

A complicating factor in the x-ray interpretations is the presence of high magnesium clays. These clays, such as the ones which occur in the Amargosa Valley, Nye County, Nevada, occur as either high magnesium bentonites or as a magnesium montmorillonite or saponite. The x-ray diffraction data compiled for saponite makes the identification of this mineral fairly easy. Interpretation of high magnesium montmorillonite (bentonite), however, is more difficult. Further studies on this aspect of the identification should solve this problem.

B. Exchangeable Chemistry

Selected samples were submitted to Coors Spectro-Chemical Labs for determination of their cation exchange capacity, exchangeable cations and soluble cations. Exchangeable and soluble cations determined were $Na^+$, $K^+$, $Ca^{++}$ and $Mg^{++}$. In addition, $Li^+$ was determined on selected samples from the Summit Range and Gunn deposits in California and the Amargosa Valley deposit in Nevada.

The exchangeable chemistry of the bentonites, and the smectite clay minerals in general, are an indication of their ion exchange capacities. This, in turn, can be used as a guide to their potential swelling characteristics. For a more detailed discussion on the mineralogy and chemistry of the smectite clays see the DSC Technical Publication by Regis (1978).

Predominantly, sodium and lithium bearing bentonites have high swelling (viscosity) properties while low sodium and high calcium bentonites have low viscosities. The chemistry can then be used as a guide for predicting the commercial applications, if any, of these bentonites. The samples were selected for chemical analysis after the x-ray and physical tests were obtained, thus those samples selected are representative of that portion of the deposit sampled.

C. Physical Properties

All of the samples collected were submitted to the BLM bentonite testing laboratory at Worland, Wyoming. Viscosity (yield) and water loss tests were obtained on all of the samples since these two properties are most indicative of the chemistry of the bentonite and also its potential commercial value. In addition, pH was also determined on some bentonites. Because of the varied mineralogy and complexities of the clay mineral assemblage in some deposits, viscosities were also run using different solution media. Samples suspected to be saponite and sepiolite were run in distilled water, tap water and a synthetic seawater composition.

RESULTS

A. <u>California</u>

An index map showing the sample locations of the California localities is shown in Figure 2.

X-Ray Diffraction Analysis:

Shown in Table 1 is the compilation of the major and minor mineralogical phases.

Both of the sampled bentonite deposits in Imperial County are Ca bentonites. In addition, they contain high amounts of impurities, primarily quartz and calcite. Minor impurities include gypsum and feldspar minerals.

The bentonite sampled at the deposit in Summit Range varies from high Ca bentonite to a mixed calcium and sodium bentonite to a Na bentonite. Major impurities in all the samples were cristobalite and tridymite. The zeolite, clinoptilolite, is a common contaminant of this deposit as well as quartz, calcite and feldspar minerals. The presence of cristobalite and tridymite would indicate that this bentonite was probably formed at a low temperature by diagenetic alteration.

The Gunn bentonite deposit is the most interesting insofar as its mineralogy is concerned. X-ray analysis indicates a suite of clay minerals which would indicate some low temperature hydrothermal activity. For example, one sample collected along a small fault zone was a mixture of sepiolite and hectorite. Also a sample collected just below its contact with the Pleistocene alluvium is believed to be a very pure saponite. In addition, the Gunn deposit also contains zeolites, primarily clinoptilolite occurs intermixed with the bentonite and also as somewhat pure monomineralic beds. Common impurities beside the zeolites are calcite, quartz and gypsum.

Chemistry:

Shown in Table 2 is the exchangeable chemistry of selected samples from the Southern California localities.

The chemistry of the two deposits in Imperial County show that both are essentially high calcium bentonite deposits. The Na/CaMg ratios are very low, indicating an exchangeable calcium and magnesium content of 75 to 95%.

The bentonite deposit in the Summit Range is essentially an intermediate Na and Ca clay. Two samples had Na/CaMg ratios of 0.82 and 0.84 or a sodium content of 45-46%. The others had somewhat lower Na/CaMg ratios, thus approaching a high calcium

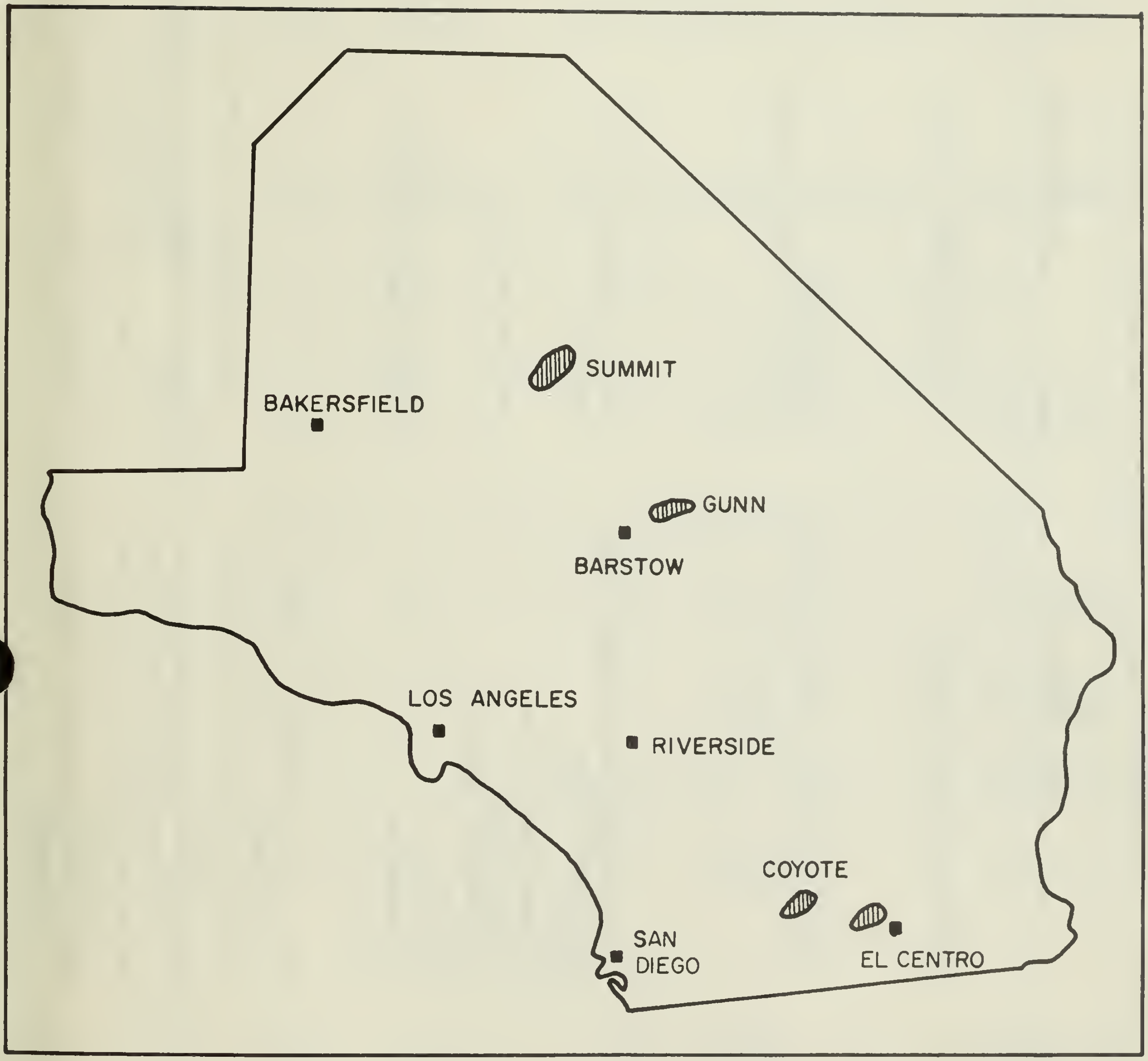



Figure 2. Index Map of Southern California Showing Sample Locations from Selected Bentonite Deposits. All Deposits Sampled are in Riverside District.

Table 1. X-Ray Diffraction Analyses of Selected Bentonites from Southern California

| Location | Major Phases | Minor Phases |
|---|---|---|
| Imperial County | | |
| Coyote Mountains | | |
| CA-CM-1 | Ca Montmorillonite; Quartz | Calcite; Feldspar; Gypsum |
| CA-CM-2 | " " ; " | " ; " ; " |
| CA-CM-3 | " " ; " | " ; " ; " |
| El Centro | | |
| CA-1-1 | Ca Montmorillonite; Quartz; Calcite | Mica; Gypsum |
| CA-1-2 | " " ; " | Calcite; Feldspar; Gypsum |
| CA-1-3 | " : ; " | " ; " ; " |
| San Bernardino County | | |
| Gunn Claims | | |
| CA-G-1 | Li-Mg Montmorillonite; Sepiolite | Quartz; Gypsum; Calcite |
| CA-G-J-1A | Na Montmorillonite | Quartz |
| CA-G-J-1B | Calcite | |
| CA-G-J-2 | Cristobalite; Calcite | |
| CA-G-WT-1 | Clinoptilolite | Unknown Zeolite?? |
| CA-G-J-3 | Ca Bentonite; Quartz | |
| CA-G-J-4 | Calcite | |
| CA-G-J-5 | Ca Bentonite | Gypsum; Quartz; Calcite |
| CA-G-J-5A | Ca Bentonite | Gypsum; Quartz; Calcite |
| CA-G-J-6 | Na Bentonite | |
| Summit Range | | |
| CA-RM-1 | Na/Ca Montmorillonite; Cristobalite; Tridymite | |
| CA-RM-2 | Ca Montmorillonite; Cristobalite; Tridymite | Quartz; Feldspar; Clinoptilolite |
| CA-RM-3 | Na Montmorillonite; Cristobalite; Tridymite | Quartz; Feldspar; Clinoptilolite |
| CA-RM-4 | Na Montmorillonite; Cristobalite; Tridymite | Feldspar; Calcite; Quartz |
| CA-RM-5 | Na/Ca Montmorillonite; Cristobalite; Tridymite | Feldspar; Quartz, Clinoptilolite |

Table 2. Exchangeable Chemistry and Physical Properties of Selected Bentonites from Southern California

| Location | Cation Exchange Capacity (meq/100 gm) | Chemistry (meq/100 gm) Na | K | Ca | Mg | Li | Na/CaMg | Physical Properties Viscosity | Water Loss (ml) |
|---|---|---|---|---|---|---|---|---|---|
| Imperial County | | | | | | | | | |
| Coyote Mountains | | | | | | | | | |
| CA-CM-1 | 33.1 | 5.3 | - | 38.7 | 8.3 | - | 0.11 | 30 | 70 |
| CA-CM-2 | 30.8 | 0.9 | - | 40.3 | 6.2 | - | 0.04 | 30 | 55 |
| CA-CM-3 | - | - | - | - | - | - | - | 30 | 70 |
| El Centro | | | | | | | | | |
| CA-I-1 | 38.3 | 9.3 | - | 22.4 | 6.2 | - | 0.04 | 30 | 122 |
| CA-I-2 | - | - | - | - | - | - | - | 30 | 112 |
| CA-I-3 | 31.8 | 1.3 | 0.7 | 40.3 | 5.1 | - | 0.33 | 40 | 55 |
| San Bernardino County | | | | | | | | | |
| Gunn Claims | | | | | | | | | |
| CA-G-1 | - | - | - | - | - | - | - | 58 | 228 |
| CA-G-J-1A | 49.2 | 49.2 | 36.1 | 0.7 | 10.2 | 9.1 | 1.9 | 91 | 21 |
| CA-G-J-1B | - | - | - | - | - | - | - | 0 | 240) not |
| CA-G-J-2 | - | - | - | - | - | - | - | 0 | 148) bentonite |
| CA-G-WT-1 | - | - | - | - | - | - | - | 30 | 173 - zeolite |
| CA-G-J-3 | 37.5 | 3.9 | 0.1 | 24.1 | 3.2 | <0.05 | 0.14 | 40 | 46 |
| CA-G-J-5 (J&J) | 59.9 | 29.5 | - | 50.2 | 3.1 | - | 0.55 | 30 | 107 |
| CA-G-J-6 | 37.8 | 18.3 | 1.0 | 13.6 | 9.0 | <0.05 | 0.85 | 80 | 33 |
| *G-2-Jule | - | - | - | - | - | - | - | 60 | 25 |
| *G-3-Jule | - | - | - | - | - | - | - | 54 | 17 |
| *G-4-Jule | - | - | - | - | - | - | - | 68 | 22 |
| *G-9-Jule | - | - | - | - | - | - | - | 39 | 16 |
| *G-10-Jule | - | - | - | - | - | - | - | 46 | 17 |
| Summit Range | | | | | | | | | |
| CA-SH-1 | 46.7 | 11.5 | 0.5 | 36.6 | 2.3 | <0.05 | 0.31 | 76 | 21 |
| CA-SH-2 | 36.5 | 3.9 | 0.2 | 42.7 | 1.4 | - | 0.09 | 30 | 38 |
| CA-SH-3 | 36.4 | 17.1 | 0.6 | 20.2 | 1.3 | - | 0.82 | 63 | 23 |
| CA-SH-4 | 41.2 | 28.3 | 0.3 | 29.5 | 4.0 | - | 0.84 | 65 | 25 |
| CA-SH-5 | 4313 | 11.7 | 0.3 | 43.1 | 3.5 | - | 0.26 | 55 | 23 |

* Physical properties taken from Ryman (1968).

type bentonite. One sample was also tested for exchangeable Li+, which would indicate the highly desirable Li rich variety of bentonite known as hectorite. This sample showed only 0.05 meq/100 gm of Li+ which would not indicate hectorite. The soluble Li+ content was also very low.

The Gunn bentonite deposit is highly varied in its exchangeable chemistry, with the four samples tested having Na/CaMg ratios ranging from 1.9 down to 0.14. The sample with the high Na/CaMg ratio would indicate a high sodium bentonite of the type commonly found in Wyoming. This deposit was also checked for Li+ content because of its close proximity to the NL Industries hectorite deposit at Newberry Springs, California. Both samples showed less than 0.05 meq/100 gm of Li+. The amount of soluble Li+ was slightly higher, 2.0 meq/100 gm which may indicate Li enriched clays somewhere within the deposit.

Physical Properties:

The physical properties of these bentonites are also shown in Table 2 with the exchangeable chemistry. The deposits in Imperial County are low in viscosity and have very high water loss. Those in the Summit Range have viscosities from 30 to 70 bbl/ton and water loss values from 21 to 38 ml. This would indicate that the bentonite in the Summit Range may be a little more versatile in its uses because of its higher viscosity and lower water loss.

The Gunn deposit varies widely in its physical properties because of its chemistry and mineralogy. It has zones of high viscosity bentonite and other areas where the viscosity is moderate to low. Water loss values are also highly variable, but generally are lower than for most Tertiary age bentonites.

B. Oregon

Sample locations are plotted on the claim map shown in Figure 3. In places, samples were collected near the common boundary line between two claims, or near a corner which would represent more than two claims. This sampling procedure assumes that the bentonite beds are continuous and of uniform quality. Samples were collected by excavation with a backhoe and from operating pits. Care was taken to select only fresh, unweathered samples, and in most cases, the samples were collected from 5 to 10 feet beneath the surface.

X-Ray Diffraction Analysis:

As shown in Table 3, almost all the samples collected from this bentonite deposit are calcium rich bentonites. Only two samples were sodium rich bentonites, Silver Wells 2-1 and Pat 2-1. Two samples, both from the Long-5 claim have a mixed content of sodium

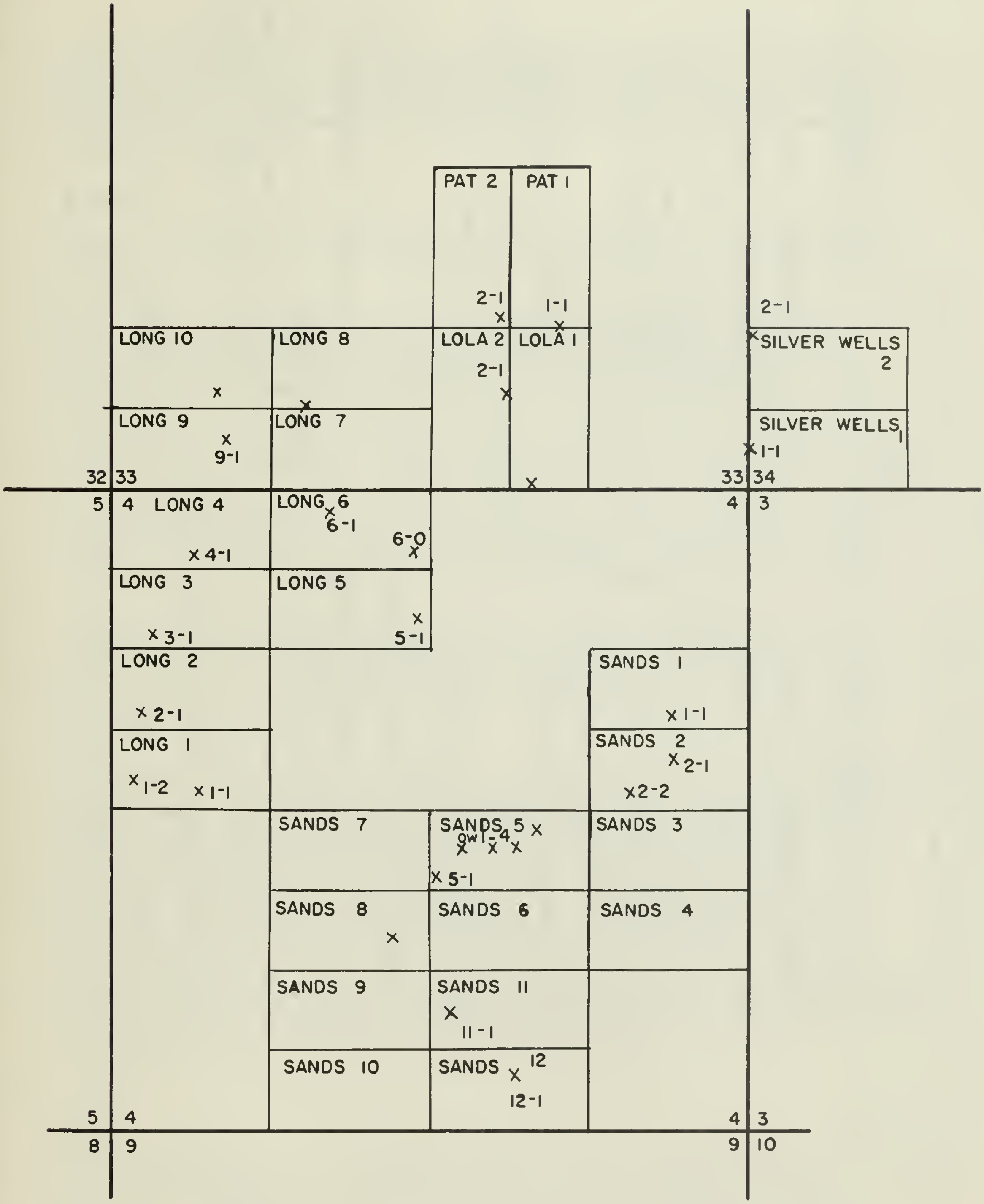



Figure 3. Claim Map Showing Sample Locations on the Weaver Bentonite Deposit, Camp Creek Area, Crook County, Oregon.

Table 3. X-Ray Diffraction Analyses of Bentonite from Camp Creek Area

| Sample | Major Phases | Minor Phases |
|---|---|---|
| Lola 1-1 | Ca Montmorillonite, Feldspar | Cristobalite, Quartz |
| Lola 1-2 | Ca Montmorillonite, Feldspar | Cristobalite, Quartz |
| Silver Wells 2-1W | Na Montmorillonite, Cristobalite | Feldspar, Quartz |
| Sands 1-1 | Ca Montmorillonite, Clinoptilolite | Feldspar, Quartz |
| Sands 5-1 | Ca Montmorillonite, Gypsum | Feldspar, Quartz |
| Sands 11-1 | Ca Montmorillonite, Mordenite | Quartz |
| Sands 12-1 | Ca Montmorillonite, Quartz | Feldspar, Clinoptilolite |
| Pat 1-1 | Ca Montmorillonite | Quartz, Cristobalite, Feldspar |
| Pat 2-1 | Na Montmorillonite, Feldspar | Quartz, Clinoptilolite |
| Long 1-2 | Ca Montmorillonite, Quartz | Feldspar |
| Long 2-1 | Ca Montmorillonite, Quartz, Feldspar | |
| Long 3-1 | Ca Montmorillonite, Quartz, Feldspar | Cristobalite, Clinoptilolite |
| Long 5-1GT | Ca Montmorillonite, Feldspar | Quartz |
| Long 5-1GM | Ca-Na Montmorillonite | Quartz, Cristobalite, Feldspar |
| Long 5-1GB | Ca-Na Montmorillonite | Quartz, Cristobalite, Feldspar |
| Long 6-1 | Ca Montmorillonite, Feldspar, Quartz | |
| Long 7-1 | Ca Montmorillonite, Quartz | Feldspar |
| Long 9-1 | Ca Montmorillonite, Clinoptilolite | |
| Long 10-1 | Ca Montmorillonite, Quartz | Clinoptilolite, Feldspar |

and calcium, and this could be considered as Ca-Na bentonite. Major impurities in most of the bentonite consists of feldspar minerals; cristobalite; the zeolite, climoptilolite; and quartz. Other mineral contaminants found include gypsum and mordenite (another zeolite).

Chemistry:

Shown in Table 4 is the exchangeable chemistry of selected samples.

The chemistry of the Camp Creek bentonite deposit also shows it to be essentially a high calcium type bentonite. The Na/CaMg ratios, with the exception of the sample off the Silver Wells claim, are all very low. They range from 0.01 to 0.42, which would indicate an exchangeable calcium and magnesium content of 70 to more than 95%. Most of the bentonite contains more than 85% exchangeable calcium and magnesium. The Silver Wells sample, with a Na/CaMg ratio of 1.38, or about 57% exchangeable sodium, occurred in the area known as the "soaphole" and probably does represent a high sodium bentonite of the Wyoming type.

The cation exchangeable capacities obtained for the bentonites from this deposit are just about what most Tertiary age bentonites run, 50-60 meq/100 gm (Regis, 1977).

Physical Properties:

The physical properties (yield and water loss) are also shown in Table 4 with the exchangeable chemistry. All of the bentonite sampled contained very low viscosities and very high water loss values. This is in line with what one might expect from high calcium bentonites. The highest swelling bentonite is the one from the Silver Wells claims which had a yield of 73 bbl/ton. The bentonite from the Long #5 claim also is moderate swelling with a yield of 70 bbl/ton. The high water loss values and low yields suggest that the bentonite is not likely to be reactive to treatment in order to bring it within the specifications for drilling muds, taconite or steel foundry uses.

C. Nevada

This clay deposit is located approximately 75 miles north of Las Vegas, Nevada. From Lathrop Wells, the claims may be reached by traveling south along Nevada State Route 29 for a distance of 6.5 miles, then eleven miles southeasterly along a mine access road. The claims lie in an area known as Amargosa Flat. Most samples were collected from mining claims in Sections 23, 24, 25, 26, T16S, R50E.

Table 4. Exchangeable Chemistry and Physical Properties of Selected Bentonites from Camp Creek Area

| Sample | Cation Exchange Capacity (meq/100 gm) | Chemistry (meq/100 gm) | | | | Physical Properties | |
|---|---|---|---|---|---|---|---|
| | | Na | Ca | Mg | Na/CaMg | Viscosity | Water Loss (ml) |
| Lola 1-1 | - | - | - | - | - | 30 | 35 |
| Lola 2-1 | 51 | 0.9 | 68.4 | 1.4 | 0.01 | 30 | 103 |
| Soap Hole 1 | - | - | - | - | - | 30 | 26 |
| Silver Wells 1-1 | - | - | - | - | - | 30 | 70 |
| Silver Wells 2-1D } | 28 | 23.6 | 15.4 | 1.7 | 1.38 | 58 | 19 |
| Silver Wells 2-1W } | | | | | | 73 | 20 |
| Sands 1-1 | - | - | - | - | - | 40 | 84 |
| Sands 2-1 | - | - | - | - | - | 30 | 114 |
| Sands 2-2 | - | - | - | - | - | 40 | 30 |
| Sands 5-1 | 50 | 2.7 | 52.5 | 5.1 | 0.05 | 63 | 26 |
| Sands 11-1 | 54 | 6.6 | 44.8 | 1.5 | 0.14 | 30 | 22 |
| Sands 12-1 | - | - | - | - | - | 30 | 71 |
| Pat 1-1B | - | - | - | - | - | 30 | 30 |
| Pat 1-1G | - | - | - | - | - | 40 | 26 |
| Pat 2-1 | 66 | 12 | 31.5 | 10.6 | 0.29 | 40 | 36 |
| Long 1-1 | - | - | - | - | - | 30 | 48 |
| Long 1-2 | - | - | - | - | - | 30 | 55 |
| Long 2-1 | - | - | - | - | - | 30 | 45 |
| Long 3-1B | - | - | - | - | - | 30 | 35 |
| Long 3-1G | - | - | - | - | - | 30 | 35 |
| Long 4-1 | - | - | - | - | - | 30 | 47 |
| Long 5-1GT | 44 | 1.8 | 46.7 | 6.4 | 0.03 | 51 | 34 |
| Long 5-1GM ) | 39 | 12.4 | 25.5 | 4.3 | 0.42 | 65 | 21 |
| Long 5-1GB ) | | | | | | 70 | 22 |
| Long 6-1 | - | - | - | - | - | 30 | 55 |
| Long 7-1 | - | - | - | - | - | 30 | 72 |
| Long 9-1 | 66 | 4.7 | 47.0 | 0.7 | 0.10 | 30 | 49 |
| Long 10-1 | 63 | 8.5 | 49.9 | 3.2 | 0.16 | 30 | 39 |
| OW-1 ) Sand #5 | - | - | - | - | - | 0 | 70 |
| OW-2 ) Sand #5 | - | - | - | - | - | 30 | 55 |
| OW-3 ) Sand #5 | - | - | - | - | - | 30 | 35 |
| OW-4 ) Sand #5 | - | - | - | - | - | 46 | 35 |

X-Ray Diffraction Analysis:

This deposit represents a magnesium-rich environment, and as a result most of the clays are high in magnesium content. As a result, associated minerals are also magnesium bearing.

According to Khoury (1977), who is completing his PhD thesis on this deposit, the presence of either saponite or high magnesium montmorillonite is often accompanied by dolomite. This is evident in Table 5, where a sample from IMV's Pit #5 was identified in the field as a saponite and confirmed by x-ray analysis. Note that dolomite is a major phase with this sample. Also, a sample from Pit #5 which is not a saponite but a high magnesium montmorillonite (Ca-Mg bentonite) shows the presence of dolomite as a minor phase. In addition to the above two magnesium clays, hectorite, or a clay similar to hectorite also occurs in the deposit. This clay was identified in samples LC-3 and CS-1. Sample LC-3 is also interesting in that a mineral very similar in structure to palygorskite or attapulgite was found also as a major phase with the hectorite. Palygorskite, $(MgAl)_2Si_4O_{10}(OH)\cdot 4H_2)$ is the aluminum rich analog of sepiolite and has never been reported from either this locality or Nevada. Thus, the possibility exists that a new mineral common to Nevada has been found. Sodium montmorillonite, comparable to Wyoming bentonite, occurs in a sample from IMV's Pit 300 on claim #E136H. This bentonite is a high sodium montmorillonite, and was extremely pure and well crystallized. The rest of the samples collected were identified as Ca rich montmorillonites, or calcium bentonites. A sample of Ca bentonite from the Kinney claim was also extremely pure and well crystallized.

Major mineral impurities occurring with the smectite clays were quartz, calcite and dolomite. Calcite was a common contaminant occurring with the high calcium bentonites. Mineral impurities consisted of gypsum and cristobalite.

The sepiolite clay minerals occur with saponite in samples from Cat 135. The sepiolite, however, is very distinctive and can be easily separated from the saponite. For this reason, the x-ray patterns obtained on sepiolite in Table 5 are essentially monomineralic as far as the clay minerals are concerned. The sepiolite bed at this locality averages about four feet in thickness. Samples Cat 135NP-NW and Cat 135NP-reworked are both from the same pit. The reworked sample, however, represents a very vuggy sepiolite which appears to have undergone some hydrothermal alteration or was subjected to penetration by a hot spring. Sepiolite is the major phase in both samples, but in the "unaltered" sepiolite, minor impurities are tridymite, cristobalite and calcite. The reworked or "altered" sepiolite contained only tridymite as an impurity. This suggests that the composition of the solutions which were in contact with

Table 5. X-Ray Diffraction Analyses of Selected Clay Minerals

Amargosa Valley, Nye County, Nevada

| Sample Description | Major Phases | Minor Phases |
|---|---|---|
| Bentonites | | |
| Kinney Claim | Ca Montmorillonite | |
| CS-1 | Li-Mg Montmorillonite, Quartz | Calcite |
| Pit 300, Claim E136H | Na Montmorillonite | |
| Shaft 5, Claim 13QR | Ca Montmorillonite, Calcite | Quartz |
| Pit 9, Claim 33K | Ca Montmorillonite, Calcite | Quartz |
| Pit 8, Production Pit | Na Montmorillonite | Quartz |
| DL Pit 5 | Ca-Mg Montmorillonite | Calcite, Domomite |
| LC-3 | Li-Na Montmorillonite, Palysorgorskite/Attapulgite | |
| NE Ewing 13 | Ca Montmorillonite | Calcite, Quartz |
| Pit 5-28528E (Saponite) | Mg Montmorillonite, Dolomite | |
| Sepiolites | | |
| Cat 135NP-NW Corner | Sepiolite | Tridymite, Cristobalite, Calcite |
| Cat 135NP-Reworked | Sepiolite | Tridymite |
| SM33DH | Sepiolite, Calcite | Cristobalite, Tridymite |

this sepiolite had to be acidic in order to dissolve the calcite and at elevated temperature in order to convert cristobalite to tridymite. This implies that the sepiolite is a fairly stable mineral. The third sepiolite sample, SM33DH, contains calcite as a major impurity and cristobalite and tridymite as minor phases.

Chemistry:

Table 6 is a compilation of the exchangeable cations of selected bentonite and saponite samples from this deposit.

Two of the bentonites have Na/CaMg ratios in excess of 1.5 which would indicate them to be high sodium bentonites. Their exchangeable magnesium contents, however, are also very high. This may be the reason why they have lower viscosities and higher water loss than such a high Na/CaMg ratio would indicate (see Table 7). Although they have been called Na bentonites by their x-ray patterns, they may consist of a mixed layered Na-Mg montmorillonite structure. Bentonite from Pit 5 and Shaft 5 localities are typical high calcium bentonites, while the sample from the Kinney claim with a Na/CaMg ratio of 0.65 is an intermediate Ca-Na bentonite according to the classification proposed by Regis (1977). All of the bentonites, however, have very high amounts of exchangeable magnesium.

The exchangeable cations in the one saponite sample have a Na/CaMg ratio of 0.39. This sample was also checked for exchangeable Li+, with less than 0.05 meq/100 gm being found. Although this sample had the x-ray pattern of a pure saponite, it contains an appreciable amount of exchangeable calcium and sodium. In addition, as can be seen from Table 7, its viscosity and water loss is typical of a high sodium bentonite. It appears, therefore, that saponites must be treated as a separate clay mineral and not be classed as a bentonite. This is not surprising when the structural significance of these two smectite minerals is considered. One can also argue that hectorite should not be considered a bentonite, but as a separate clay mineral. The physical properties of hectorite, however, are similar to sodium bentonite and can be correlated with its NaLi/CaMg ratios. This is not the case with saponite.

Physical Properties:

The physical properties shown in Table 7 are on bentonite, saponite and sepiolite from operating pits owned by IMV Inc. The viscosities and water loss values for the sepiolites were run in three solution media to measure their changes in viscosity and water loss for distilled, tap and seawater. As you can see, sepiolite is affected by the amount of soluble sodium chloride in the solutions in the opposite manner as high sodium bentonites. The latter will decrease in viscosity in seawater while sepiolite either stays the same or increases in viscosity. This, then, makes sepiolite a potential valuable drilling mud for either off-shore

Table 6. Exchangeable Chemistry of Selected Bentonites and Saponite from Amargosa Valley, Nye County, Nevada

| Sample Description | Cation Exchange Capacity (meq/100 gm) | Chemistry (meq/100 gm) Na | K | Ca | Mg | Li | Na/CaMg |
|---|---|---|---|---|---|---|---|
| A. Bentonites | | | | | | | |
| Kinney Claim | 87 | 27.0 | 4.3 | 15.0 | 35.1 | - | 0.65 |
| Pit 300, Claim E136H | 84 | 47.7 | 3.7 | 9.5 | 22.9 | - | 1.59 |
| Shaft 5, Claim 13 | 93 | 5.1 | 1.6 | 55.3 | 22.8 | - | 0.08 |
| Pit 8, Production Pit | 85 | 44.3 | 5.9 | 9.8 | 23.2 | - | 1.52 |
| D. L. Pit 5 (Saponite?) | 22 | 2.4 | 0.9 | 23.3 | 15.7 | - | 0.09 |
| B. Saponite | | | | | | | |
| D. L. Pit 5, 28S28W | 35 | 8.7 | 1.4 | 12.5 | 13.3 | 0.05 | 0.39 |

Table 7. Physical Properties on Sepiolite, Saponite and Bentonite, Amargosa Valley, Nye County, Nevada

| Sample Description | Apparant Viscosity | Yield | Water Loss | pH |
|---|---|---|---|---|
| A. Bentonites | | | | |
| Kinney Claim | 4/2 | 40 | 40.0 | 9.0 |
| Pit 300, Claim E136H | 27/2 | 89 | 21.5 | 8.6 |
| Shaft 5, Claim 13QR | 3/2 | 30 | 75.0 | 8.8 |
| Pit 9, Claim 33K | 5/2 | 46 | 95.0 | 8.5 |
| Pit 8, Production Pit | 9/2 | 61 | 19.0 | 8.8 |
| DL Pit 5 | 5/2 | 46 | 40.0 | 9.4 |
| Pit 5, 28S28W (Saponite) | 35/2 | 96 | 13.0 | 9.3 |

| | Medium | Apparant Viscosity | Yield | Water Loss | pH |
|---|---|---|---|---|---|
| B. Sepiolite | | | | | |
| Cat 135NP-NW Corner | Distilled | 79/2 | 116 | 64.0 | 8.6 |
| | Tap | 106/2 | 121 | 83.0 | 8.4 |
| | Seawater | 119/2 | 122 | 93.0 | 7.7 |
| Cat 135NP-Reworked | Distilled | 102/2 | 120 | 42.0 | 8.7 |
| SM33DH | Distilled | 8/2 | 58 | 58.0 | 9.2 |
| | Tap | 13/2 | 70 | 77.6 | 8.6 |
| | Seawater | 14/2 | 71 | 96/2 | 7.3 |
| Cat 135, NP1, Pit 4 | Distilled | 53/2 | 108 | 112.2 | 8.1 |
| | Tap | 52/2 | 107 | 137.0 | 8.1 |
| | Seawater | 35/2 | 96 | 152.0 | 7.5 |

drilling or in deep geothermal wells containing high mineral content effluents. The water loss values of sepiolite is very high, thus their wall building characteristics as a drilling mud is poor. Treatment by organic polymers or other chemicals may lower the water loss to acceptable levels. The viscosities for the sepiolites sampled are very high, ranging from 71 to 121 bbl/ton yield. The low viscosity (71 bbl/ton) shown for sample SM33 is due to the high percentage of calcite in the sepiolite.

The viscosities and water loss of the bentonites vary from a high of 89 to a low of 30 bbl/ton, and water loss from 19 to 95 ml. These values can be correlated to some extent with their mineralogy and exchangeable cation ratio - Na/CaMg. The one saponite sample from Pit 5 has a high viscosity of 96 bbl/ton and a low water loss (13 ml) which is the same as high sodium Wyoming and Montana bentonites. Such properties make it potentially valuable for all uses requiring swelling bentonite.

D. Idaho

These two deposits both lie in Owyhee County, The Ben-Jel deposit is approximately 8 miles southeast of Orena, and the Opalene Gulch locality occurs 9 miles south of Marsing.

According to Anstett (1977) the Ben-Jel deposit consists of a portion of the Middle Pliocene Chalk Hills Formation of the Idaho Group. In the area of the Ben-Jel mine, the bentonite is exposed over an area of 500 to 700 feet, with thickness ranging from 15 to 35 feet. The Opalene Gulch deposit occurs within the Poison Creek Formation also of the Idaho Group. This deposit is Lower Pliocene in age. Samples were collected from 40 foot high erosional remnant of unknown thickness. There has been no reported production from this site, although the deposit shows considerable mining activity.

X-Ray Diffraction Analysis:

The Ben-Jel deposit consists of a mixture of mainly Na and intermediate Na-Ca montmorillonite and the zeolite clinoptilolite. Two of the six samples (BJ-4 and BJ-6) consisted essentially of monomineralllic zeolite. All of the montmorillonite had their (001) reflections between 6° and 7°2θ or 14.7 Å to 12.6Å which would indicate mixed Na-Ca and Na montmorillonites, thus the x-ray diffraction data would suggest that this deposit is primarily an intermediate Na-Ca bentonite with interlayered zeolites. All of the numbers examined were heavily contaminated with cristobalite, tridymite or quartz. Minor phases were also the quartz silica minerals, in addition to gypsum and Ca montmorillonite (Table 8).

The Opalene Gulch bentonite consists almost entirely of Ca and intermediate Ca-Na montmorillonite. Like the Ben-Jel deposit, the zeolite. clinoptilolite, is also a common constituent. Gangue minerals include cristobalite, quartz, gypsum and feldspar. This bentonite deposit is also heavily contaminated with these minerals.

Table 8. X-Ray Diffraction Analysis of Bentonite from Owyhee County, Idaho.

| Sample and Location | Major Phases | Minor Phases |
| --- | --- | --- |
| Ben-Jel Mine: | | |
| BJ-1 | Na-Ca montmorillonite, Cristobalite | Tridymite, Quartz |
| BJ-2 | Na montmorillonite, Cristobalite | Tridymite |
| BJ-3 | Na montmorillonite, Cristobalite, Tridymite | Guartz, Gypsum |
| BJ-4 | Clinoptilolite | Quartz, Ca montmorillonite |
| BJ-5 | Na-Ca montmorillonite, Quartz | ----- |
| BJ-6 | Clinoptilolite, Quartz | Cristobalite, Feldspar, Ca montmorillonite |
| Opalene Gulch Site: | | |
| OG-1 | Ca and Ca-Na montmorillonite, Clinoptilolite, Cristobalite, Quartz | Feldspar |
| OG-2 | Ca and Ca-Na montmorillonite, Cristobalite | Quartz, Feldspar |
| OG-3 | Ca-Na montmorillonite, Cristobalite | Quartz, Feldspar, Tridymite, Gypsum |
| OG-4 | Ca montmorillonite, cristobalite | Tridymite, Quartz, Clinoptilolite |

Chemistry:

The exchangeable chemistry, together with physical properties of both deposits are shown in Table 9. The bentonite at the Ben-Jel Mine is primarily a Na montmorillonite. Three samples which were examined for their exchangeable cation content had Na/CaMg ratios in the intermediate Na-Ca montmorillonite range (Regis, 1978). One sample, BJ-3, had a Na/Ca Mg ratio of 2.2 which clearly indicates a high Na bentonite. The viscosities and water loss values, however, are not indicative of the Na/CaMg ratios. This is probably due to a number of reasons, the most important being the high amounts of contaminant mineral phases in the bentonite. Sample BJ-3, which had the highest Na/CaMg ratio, contained major amounts of cristobalite and tridymite in addition to gypsum and quartz. Samples BJ-4 and BJ-6 were not even bentonite but zeolites. In fact, the BJ-6 sample upon which exchangeable chemistry was obtained is interesting in that although it did contain a small amount of Ca montmorillonite, the chemistry indicates the ion-exchange properties of the zeolite.

The Opalene Gulch deposit is essentially a Ca and intermediate Ca-Na bentonite. Of the one sample analyzed for its exchangeable chemistry, OG-2, the Na/CaMg ratio was only 0.07. Also, all of the viscosities and water loss were lower and higher than that material from the Ben-Jel deposit. Mineral impurities still would play a factor in the viscosities, but the higher water loss values would indicate high Ca bentonite.

The cation exchange capacities for both of the Idaho bentonites are somewhat lower than other Tertiary bentonites. It is interesting to note that sample BJ-6, which is a zeolite, had about the same cation exchange capacity as the bentonite.

## E. Arizona

This deposit is located east and north of Yuma, Arizona, approximately 7 miles north and east of Welton, Arizona. The samples came from an excavation site where a small amount of bentonite has been mined for cosmetic and pharmaceutical uses. The bentonite zone sampled was 19 inches. This pit is located in S1/2, SE1/4 NW1/4, Sec. 1, T8S., R18W. The other sample was from the same bentonite bed in approximately the same location.

X-Ray, Chemistry and Physical Properties:

According to Vanderzyl (1977), this deposit is probably no older than late Oligocene or younger than middle Miocene. A columnar section, prepared by Vanderzyl is shown in Figure 4. Also shown is a lithologic description of the sedimentary sequence at this locality. The various properties of this bentonite is compiled in Table 10. Exchangeable chemistry was obtained on both of the

Table 9. Exchangeable Chemistry and Physical Properties of Selected Bentonites from Owyhee County, Idaho.

| Sample and Location | Cation Exch. Capacity (Meq/100 gm) | Chemistry (meq/100gm) Na | K | Ca | Mg | Na/CaMg | Physical Properties Viscosity | Water Loss |
|---|---|---|---|---|---|---|---|---|
| Ben-Jel Mine: | | | | | | | | |
| BJ-1 | 24.1 | 9.5 | 0.3 | 0.2 | 11.4 | 0.84 | 58 | 34 |
| BJ-2 | ---- | --- | --- | --- | ---- | ---- | 46 | 45 |
| BJ-3 | 24.0 | 12.5 | 0.3 | 0.5 | 5.3 | 2.21 | 61 | 30 |
| BJ-4 | ---- | --- | --- | --- | ---- | ---- | 30 | 126 |
| BJ-5 | 28.0 | 11.0 | 0.1 | 6.9 | 9.1 | 0.69 | 55 | 31 |
| BJ-6 | 28.4 | 5.1 | 0.2 | 6.1 | 1.6 | 0.69 | 30 | 47 |
| Opalene Gulch Site: | | | | | | | | |
| OG-1 | ---- | --- | --- | --- | ---- | ---- | 30 | 47 |
| OG-2 | 24.6 | 1.1 | 0.1 | 6.7 | 11.2 | 0.07 | 46 | 52 |
| OG-3 | ---- | --- | --- | --- | ---- | ---- | 40 | 90 |
| OG-4 | ---- | --- | --- | --- | ---- | ---- | 30 | 124 |

Table 10. X-Ray, Exchangeable Chemistry and Physical Properties of Bentonite from Yuma County, Arizona.

| Sample Location | X-Ray Diffraction Analysis Major Phases | Minor Phases |
|---|---|---|
| Yuma #1-Prod. Pit | Ca Montmorillonite (mixed layered), Quartz | Kaolinite, Feldspar, Calcite |
| Yuma #2-Select | Ca Montmorillonite (mixed layered), Quartz | Kaolinite, Feldspar, Calcite |

| | Cation Exch. Capacity | Chemistry (meq/100 gm) | | | | | Physical Prop. | |
|---|---|---|---|---|---|---|---|---|
| Sample Location | (Meq/100gm) | Na | K | Ca | Mg | Na/CaMg | Visco-sity | Water Loss |
| Yuma #1-Prod. Pit | 19.5 | 0.2 | 0.2 | 46.1 | 4.4 | 0.01 | 30 | 75 |
| Yuma #2-Select | 19.4 | 0.2 | 0.3 | 45.0 | 5.4 | 0.01 | 30 | 135 |

Arizona samples because they were almost identical in appearance and composition (x-ray), and it was thought that this would also serve as an analytical check.

X-Ray diffraction studies on the Yuma County bentonite showed them to be unusual in that the montmorillonite is of the mixed layer type, consisting of Ca montmorillonite and a mica layer which is either chlorite or illite. This is the first time such a mixed layer of montmorillonite clay of Tertiary age was found during this study. Such mixed layered clays are more common in Cretaceous age bentonites. The Yuma County montmorillonite, however, can be classified as a high Ca clay or bentonite. This is especially evident from the exchangeable chemistry obtained on these bentonites. Both samples had Na/CaMg ratios of less than 0.01 which would almost make them a "pure Ca bentonite". The low viscosities and very high water losses also indicate a very high calcium content.

Another interesting feature of this clay deposit is the presence of kaolinite clay in addition to the mixed layered montmorillonite. Again, this is the first time kaolinite was found in this study, although such an association of the two clay types is not uncommon. The only major mineral impurity occurring with this bentonite is quartz. Minor impurities, beside kaolinite, are calcite and feldspar minerals.

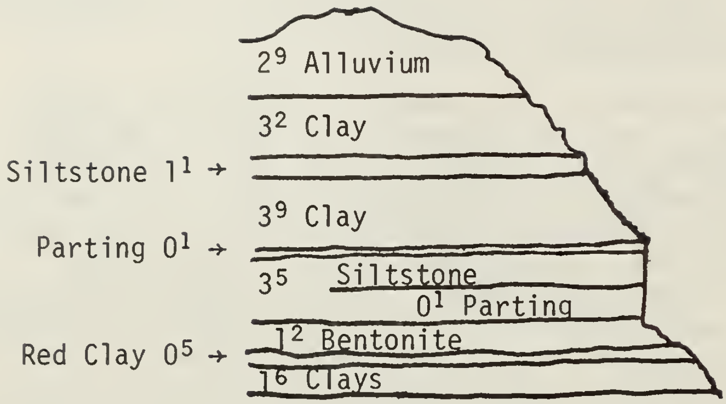
F. Utah

This deposit represents the only Cretaceous bentonite examined for this study. According to Janssen (1977), the sampled material comes from the Brushy Basin member of the Morrison formation. Four bentonitic beds were sampled in place and two stockpile at separate locations. The in-place material on one stockpile sample came from Sec. 12, T36S, R22S. The other stockpile sample was from Sec. 33, T34S, R24E.

X-Ray and chemical analysis were not obtained on these samples.

Physical Properties:

A columnar section of a portion of the Brushy Basin member of the Morrison formation, prepared by Bob Janssen, is shown in Figure 5. The sample locations from this deposit are also shown on this section. Shown in Table 11 is a compilation of the physical properties of samples taken from this deposit. All have low yields, 30-40 bbl/ton, and water losses which range from a low of 20.0 ml near the bottom of the section to a high of 44.0 ml at the topmost bed of the section. The water loss then increases from the bottom toward the top. The stockpiled sample (10) which was taken from the main working pit, had a yield of 30 bbl/ton and the highest water loss of all the samples, 60.5 ml.

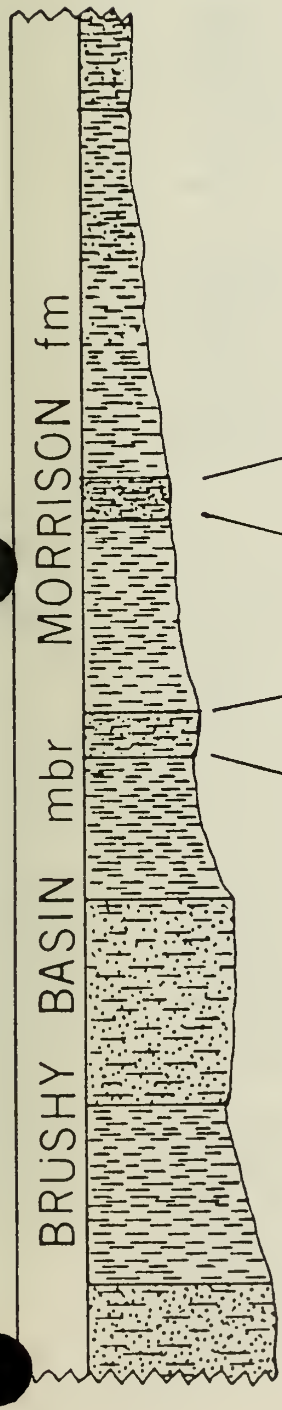



Section 1" = 10'

| | |
|---|---|
| 0 - 2.9 | Alluvium - weathered with cobbles. |
| 2.9 - 6.1 | 3.2 of dark red (oxblood) colored clay (bentonitic), sticks on teeth and has little grit. |
| 6.1 - 7.3 | 1.1 Cream colored siltstone (fine grained sandstone) |
| 7.3 - 11.1 | 3.9 Buff to red brown colored clay (bentonitic). Cleaves readily on bedding - sticks to teeth and is somewhat gritty. Shows selenite on fractures. |
| 11.1 - 11.2 | 0.1 Gray - salt and pepper - hard parting - finely crystalline (calcareous). |
| 11.2 - 14.7 | 3.5 Cream colored siltstone (fine grained sandstone) with 0.1 parting in the middle. |
| 14.7 - 16.4 | 1.7 Cream to buff colored bentonite - quite brittle with some concave fracturing - sticks on teeth and has little grit. |
| 16.4 - 16.9 | 0.5 red gritty clay with selenite on fractures. |
| 16.9 - 18.5 | 1.6 red to buff colored alternating clays - fractures on bedding plane. |

Figure 4. Columnar Section of Bentonite Bed, S 1/2, SE 1/4, NW 1/4, Section 1, T 8S, R 18W, G&SRM, Welton, Yuma County, Arizona.

FIGURE 5. Columnar Section of a Portion of
Brushy Basin Member
Morrison Formation
Sec. 12, T. 36 S., R. 22 E., SLM, Utah




| Thickness Ft. | Description |
|---|---|
| Not Meas. | Sandy Mudstone or Siltstone interlayered with bentonitic sandy units. Not sampled. |
| 11.3 | Bentonitic Claystone, some lenses and stringers of mudstone or sandy claystone. Light pink in color weathering to a darker pink. Sample Nos. 6, 7, 8, and 9 taken. |
| 1.1 | Mudstone, gray to very dark gray. Discontinuous and varies in thickness. |
| 6.2 | Bentonitic claystone, light pink weathering to a darker pink. Sample Nos. 4 and 5 taken. |
| 1.2 | Mudstone and very fine Sandstone, light gray to dark greenish gray and dark red. Not sampled. Discontinuous and varies in thickness. |
| 4.5 | Bentonitic Claystone, light gray weathering to light pink. Sample Nos. 2 and 3 taken. |
| 6.5 | Mudstone and Siltstone, gray, not sampled. |
| 5.7 | Bentonitic Claystone, fresh and weathered color - gray. Sample No. 1 taken. |
| Not Meas. | Fine Sandstone or Siltstone, bluish gray. Not sampled. |

Table 11. Physical Properties of Bentonite from Morrison Formation, San Juan County, Utah.

| Sample Description | Viscosity Yield | Water Loss | pH |
|---|---|---|---|
| 1-Bottombed-14" | 40 | 20.0 | 8.4 |
| 2-Bottom-2nd Bed-13" | 30 | 26.0 | 8.5 |
| 3-Top-2nd Bed-12" | 40 | 32.0 | 8.6 |
| 4-Bottom-3rd Bed-12" | 30 | 30.0 | 8.5 |
| 5-Top-3rd Bed-7" | 30 | 27.0 | 8.2 |
| 6-Bottom-4th Bed-13" | 30 | 32.0 | 8.3 |
| 7-Outcrop-4th Bed-10" | 30 | 37.0 | 8.2 |
| 8-Outcrop-7" | 40 | 34.0 | 8.2 |
| 9-Middle-5th Bed-18" | 30 | 44.0 | 8.6 |
| 10-Stockpile Sample | 30 | 60.5 | 8.5 |
| 11-Stockpile-T34S,R24E | 40 | 25.0 | 8.1 |

DISCUSSION

California:

The four deposits sampled in the Riverside District and Southern California are all Tertiary age bentonites. The one deposit just west of El Centro is probably younger than the others and may even be early Pleistocene in age.

A. Imperial County Bentonite

This bentonite, using the classification proposed by Regis (1977) is of the high calcium type. Such a bentonite is somewhat restricted in usage to animal feed binders, pet adsorbents and other uses not requiring a swelling type bentonite.

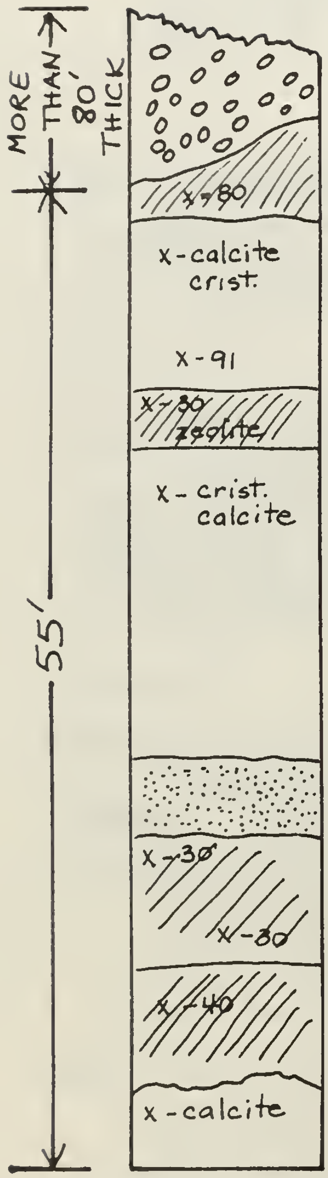
B. Summit Range Bentonite

This deposit would be classified as an intermediate or Ca-Na bentonite. There may be zones where the viscosity and water loss could make it valuable for drilling mud, taconite and steel foundry uses. Based on the samples taken from this deposit, however, its uses would be similar to those listed for the bentonite in Imperial County. In addition, this bentonite could find some markets as pond sealants, reservoir linings and possibly some civil engineering applications.

C. Gunn Bentonite Deposit

This bentonite is highly variable in mineralogy, chemistry and physical properties. The samples collected at this deposit came from a 55 foot section of intermixed clay minerals, zeolites and calcite. Shown in Figure 6 is an idealized section of the deposit showing the relative sample localities. The thickness of this zone was measured from its upper contact with alluvium to the bottom of a long narrow excavation on the Jule claim, near the SE1/4 NW1/4 Sec. 22, T10N, R22E. This deposit appears to be an erosional remnant and was probably much larger in early Pleistocene time. The thickness of the Pleistocene overburden is variable, but in archeological control pit #1, the alluvium reaches a thickness of 77 feet, without reaching the Tertiary sediments. Roughly outlined the bentonite exposures on aerial photographs, and using an average total thickness of all the bentonite beds, it is doubtful if more than 180,000 tons of bentonite occurs in this deposit, regardless of quality.

The classification of the Gunn bentonite would probably be similar to that in the Summit Range, an intermediate Ca-Na bentonite. The uses would be the same as discussed earlier. The low water loss values which the deposit appears to have would make it valuable for pond sealants and possibly taconite and foundry bentonite. There may be zones of high Na bentonite, but the complexity of the whole sedimentary sequence could make a commercial venture costly, unless some method of selective mining is feasible.




Pliestocene alluvium - at least 80' thick.

Brownish bentonite and/or saponitic clay. At least 1' thick.

Very white zone, mixture of calcite, clay and quartz minerals. Approximately 10-15' thick.

Green bentonite, 1-2' thick.

Intermixed zone, at least 25' thick, made up of layers of toffaceous sandstone, shale, bentonite, zeolites.

Toffaceous sandstone. Approximately 5' thick.

White to gray to tan colored bentonite. Approximately 6' thick.

Green bentonite. Approximately 1-2' thick.

Silicious hot spring deposits - bottom not exposed. Some clay intermixed. At least 3' exposed.

Figure 6. Idealized Section Through Tertiary Sediment Zone. Location is approximately in the SE1/4 SW 1/4 Sec. 22, T10N, R2E.

x = sample localities and either x-ray phase or viscosity.

Oregon:

The Camp Creek bentonite deposit is Tertiary in age and a part of the Oligocene to early Miocene John Day Formation. The physical exchangeable chemical properties are typical of Tertiary age bentonites. The deposit is primarily of the high calcium bentonite type, using the classification proposed by Regis (1978). Such a bentonite is restrictive in its usage to animal feed binders, pet adsorbents, pond sealants and other uses not requiring a swelling type bentonite. The deposit as a whole averages about 46 bbl/ton and has an average water loss of 45 ml. Bentonite with low water loss values, below 25 ml, could find possible markets as pond sealants, reservoir linings and perhaps some civil engineering applications. All of the bentonite is suitable as pet adsorbents as evidenced by the fact that this material is currently mined and marketed from a portion of the deposit.

Nevada:

The Amargosa clay deposit represents a complex assemblage of clay minerals, all which occur in essentially highly pure monomineralic beds of minable thickness. It represents probably the only potential commercial sepiolite and saponite deposits in the U.S. and also contains the whitest calcium bentonite in the Western U.S. Because of this assemblage of clay minerals, this deposit cannot be called a bentonite deposit or compared to other bentonite deposits in the Western U.S. Although it contains significant amounts of bentonite, it occurs associated with the other clay minerals, and does not constitute the major tonnage of the deposit.

Preliminary investigation of the bentonite in this deposit indicates that the calcium variety is probably the most common in occurrence. This bentonite is low swelling, but reactive to cation exchange. The calcium bentonite examined has a high mineralogical and chemical purity, and in turn, a high reflectivity index as a measure of their white color. This property may open up additional uses which require whiteness such as cosmetics and pharmaceutical applications.

The sepiolite which occurs at this locality is fine grained, massive and ranges in color from tan to white. Its composition is a hydrous magnesium silicate, $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$. The sepiolite and other clay minerals in the deposit are believed to be Pleistocene in age and represent a complex lake bed sedimentary sequence. Introduction of late Pleistocene and recent hot spring activity and subsequent faulting did much to produce the clay mineral assemblage occurring here and also the high magnesium content of the clays. This deposit is probably the result of the alteration of Tertiary volcanic sediments by hot, magnesium rich water. This would imply a low hydrothermal alteration genesis for the origin of the clay minerals. Differences in clay minerals could be the result of variations in the chemistry of the volcanic sediments and their proximity to the hot spring activity and burial depth. The sepiolite sampled showed high viscosity (yield) in both fresh and saltwater solutions. This, together with its stability in acid solutions could open up a wide variety of uses.

Saponite occurs primarily associated with the sepiolite. Unlike sepiolite, saponite is a smectite clay mineral and thus closely related in structure and chemistry to montmorillonite. Saponite is the high magnesium variety of montmorillonite and has the following composition:

$$(Mg_{2.92}Fe^{+3}_{0.08}Fe^{+2}_{0.03})(Si_{3.40}Al_{0.60})O_{10}(OH)_2$$

↑ ↑

The Mg++ in saponite has completely replaced the $Al^{+3}$ in the octahedral layer. The x-ray, chemical and physical property analyses obtained on probable saponite samples in this report indicate that the saponite might occur as well crystallized material exhibiting very high swelling properties and as less crystallized saponite which is essentially low swelling. Because of its high magnesium content, however, low swelling saponite with sufficient parity and composition could find possible application in high temperature ceramics and magnesia refractories.

Additional sampling and in greater detail will provide a clearer understanding of the chemistry and physical properties of this deposit.

Idaho:

The Ben-Jel deposit is one of the few Tertiary age Na and intermediate Na-Ca bentonite deposits. If it were not for the high amount of mineral impurities in this bentonite, its viscosities would be much higher. An interesting feature of this deposit is the presence of the zeolite mineral, clinoplilolite, which is apparently being mined, stockpiled and sold as a bentonite.

This deposit is of high enough grade to be able to furnish better than average clay for use as pond sealants, animal feed binders, pet adsorbents, and some crude engineering uses. Because of the high amounts of impurities and zeolites, this deposit would probably not be able to compete for markets such as oil drilling muds, taconite and foundry uses.

The other Idaho deposit, Opalene Gulch, is high Ca bentonite with corresponding low yields and high water losses. Uses for this material would be severely limited to only pure, minable layers.

Arizona:

The Tertiary bentonite in Yuma County is a high calcium montmorillonite, almost a "pure Ca-bentonite". The interesting feature of this deposit is the presence of kaolinite and mixed layer montmorillonite - illite/chlorite. The viscosity of this bentonite is very low and accordingly also has very high water losses. This clay, however, is very fined grained, uniform in color, and has highly sectile texture. It has been mined just recently for use in cosmetics and pharmaceuticals - such uses would require the extremely fine particle sizes which this clay appears to have.

Utah:

The high water loss and low viscosities of this Cretaceous bentonite would indicate that it is probably either a high calcium bentonite or an intermediate calcium-sodium bentonite at best. Such a material is highly restrictive in use, primarily as pond or irrigation canal sealant, animal feed binders and pet adsorbents.

For the most part, all of the deposits examined in this study are intermediate calcium-sodium bentonites and high calcium bentonites. There are "spot" occurrences of high sodium clay similar to Wyoming bentonite, however, these deposits are limited in size or tonnage.

The cation exchange capacities of the Tertiary bentonites are generally lower than the average of 68 meq/100 gm obtained for Wyoming and Montana bentonites. The Tertiary bentonites examined in this report averaged 58 meq/100 gm cation exchange capacity. The deposit at Amargosa Valley, Nevada however far exceeded the average obtained for typical Tertiary age bentonites, and those from Idaho, and Arizona were far below the average cation exchange capacity.

With the exception of the deposit in the Amargosa Valley, Nevada, all of the deposits sampled are currently, or have been in the recent past, mined for uses such as animal feed binders, pond and irrigation canal sealants, and pet adsorbents. Thus, they appear not to have any impact on the Wyoming bentonite markets. The Nevada deposit owned by INV Inc., because of its complex clay assemblage, is mining and marketing clays for many of the same uses as Wyoming bentonite.

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